Appendix D

IDEP Field Protocol Manual

MICHIGAN DEPARTMENT OF TRANSPORTATION

Illicit Discharge Elimination Program

FIELD PROTOCOL MANUAL

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CONTENTS

APPENDICES

LIST OF TABLES AND FIGURES

Tables

Figures

INTRODUCTION

PHASE I ILLICIT DISCHARGE ELIMINATION REQUIREMENTS

The United States Environmental Protection Agency's (EPA) Phase I Storm Water regulations require all regulated MS4 communities and agencies to address six minimum measures. Among these six measures there are the Illicit Discharge Detection and Elimination Minimum Control Measure. Under the regulations, this measure must include the following:

- A storm sewer system map showing the location of all outfalls and the names and location of all waters of the United States that receive discharges from those outfalls.
- Through an ordinance, or other regulatory mechanism, a prohibition on non-storm water discharges into the MS4 community, and appropriate enforcement procedures and actions.
- A plan to detect and address non-storm water discharges, including illegal dumping, into the MS4 community.
- The education of public employees, businesses, and the general public about the hazards associated with illegal discharges and improper disposal of waste.
- The determination of appropriate best management practices (BMPs) and measurable goals for this minimum control measure.

WHAT IS AN ILLICIT CONNECTION?

An illicit connection is the discharge of pollutants or non-storm water materials into a storm sewer system via a pipe or other direct connection. Sources of illicit connections may be sanitary sewer taps, wash water from Laundromats or carwashes, footing drains, and other similar sources.

WHAT IS AN ILLICIT DISCHARGE?

An illicit discharge is the discharge of pollutants or non-storm water materials to storm sewer systems via overland flow, or direct dumping of materials into a catch basin. Some examples of illicit discharges include the overland drainage from a carwash, or dumping used motor oil in or around a catch basin.

WHAT ARE ACCEPTABLE NON-STORM WATER DISCHARGES?

Acceptable non-storm water discharges include:

- Water line flushing
- Landscape irrigation runoff
- Diverted stream flows
- Rising groundwater
- Uncontaminated groundwater infiltration
- Pumped groundwater
- Discharges from potable water sources
- Foundation drains
- Air conditioning condensate
- Irrigation water
- Springs
- Water from crawl space pumps
- Footing drains
- Lawn watering runoff
- Water from non-commercial car washing
- Flows from riparian habitats and wetlands
- Residential swimming pool discharges and other de-chlorinated swimming pool discharges
- Residual street wash waters
- Discharges or flows from emergency fire fighting activities

PURPOSE OF THIS PROTOCOL MANUAL

The purpose of this manual is to define the procedures for the illicit discharge elimination plan. The manual will review the steps used to find and locate illicit connections/discharges including:

- Identifying outfalls
- Visiting outfalls
- Recognizing problems

- Tracking the problems upstream
- Identifying the source

The methods of storing the data and information regarding health and safety issues are also included in this appendix.

STEPS TO FIND AND LOCATE ILLICIT CONNECTIONS/DISCHARGES

The steps to finding, locating illicit connections and discharges can be grouped into four sections. Office work prior to the sampling includes locating outfalls and manholes, developing a daily work plan preparing traffic control plans, and five-day advance notice to MDOT of these plans. Prior to the site visit metrological data, equipment, calibrations and bottle supplies must be checked. A field site visit can then be made where inventories and screenings are completed and samples are collected for each outfall. Following the site visit samples must be delivered to the lab. Inventory and screening data must be to the main database after the visit, and test results entered when they are received. Figure 1 represents this step-by-step process. Additional details can be found in the subsequent chapter.

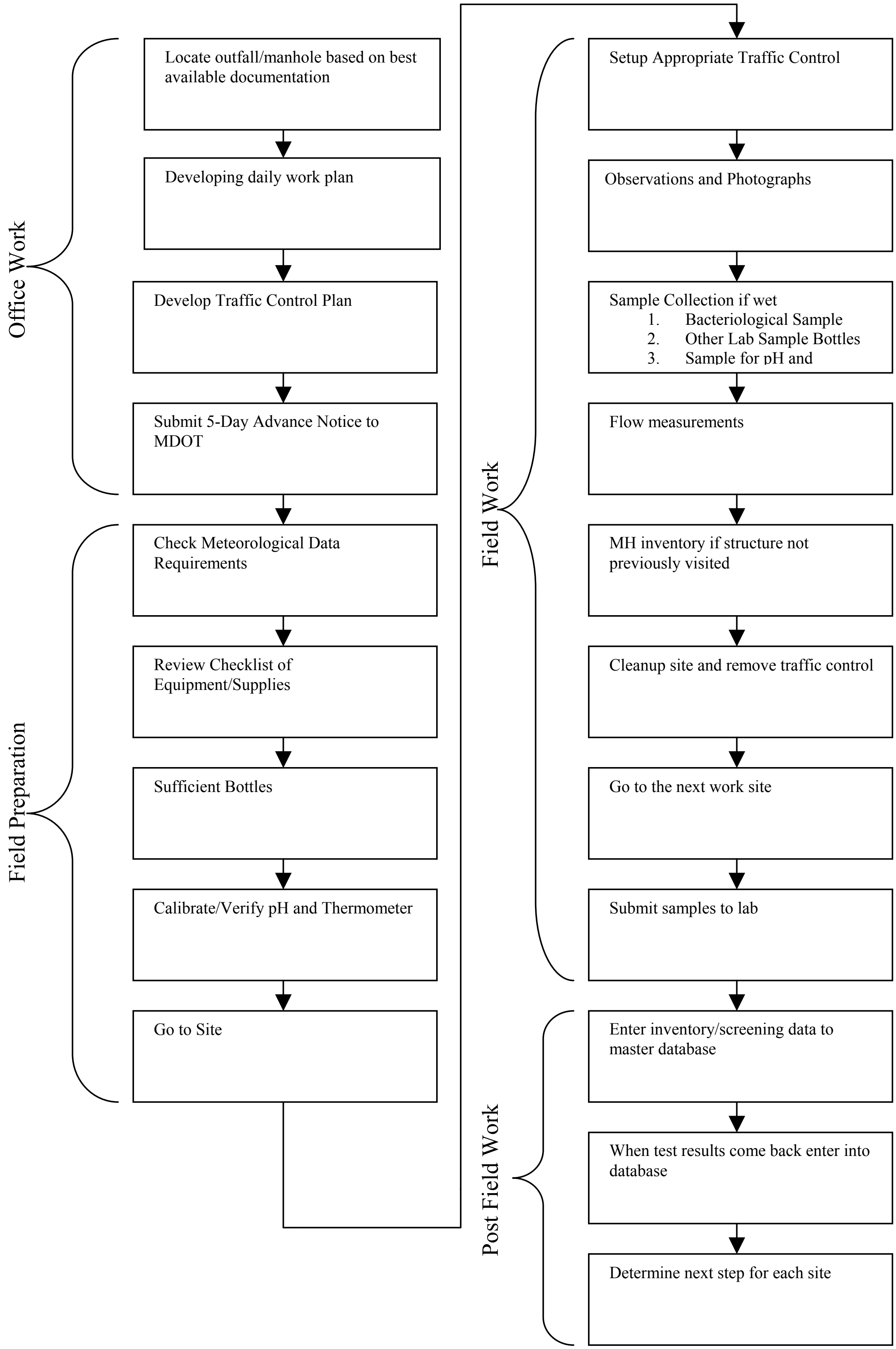
IDENTIFYING OUTFALLS

Locating Outfalls

In the permitting process, outfalls were identified by using the best data available at the time. In the implementation phase, these outfalls will need to be confirmed and any previously unidentified outfalls must be located. The following steps will be used to identify previously known and unknown outfalls.

1. Obtain the best available base map.
2. Locate on the base map all previously identified outfalls from the original permit.
3. Obtain the best available storm water system maps from any other available sources.
4. Plot the available information on base map.
5. Review on paper the locations of all known outfalls and the location of all known construction projects over the last 10 years.
6. Update the base map according to the information obtained.
7. Go into the field and walk the system verifying the location of the previously identified storm water system outfalls and visually look for any missed outfalls. During this phase of the work the field crews should look for logical locations of outfalls not already identified on the maps, i.e., and low points along the road. This step is to be performed concurrent with the field screening tasks.

Figure 1 Project Flow Chart



NOTIFICATION PROCEDURES

Prior to any work in the field, notification shall be given to the respective MDOT office on using the five-day advanced notice form. This form will require information pertaining to where fieldwork is taking place. Any work that causes an obstruction to traffic flow, e.g. lane closures, shall be worked out ahead of time with the respective MDOT office 48-hours in advance. Obstruction to traffic may be limited by time of day; day of the week and other construction related ongoing activities. A copy of the statewide permit to work within the MDOT ROW must be carried in work vehicle at all times.

VISITING OUTFALLS

When to Visit

Outfalls should be visited only during periods of dry weather in order to minimize the chance of observing storm water in the storm sewer system. As a general rule of thumb, dry weather can be defined as 72 hours of less than 0.10 inches of total precipitation.

Equipment

A list of necessary equipment for visiting outfalls is located in Appendix A.

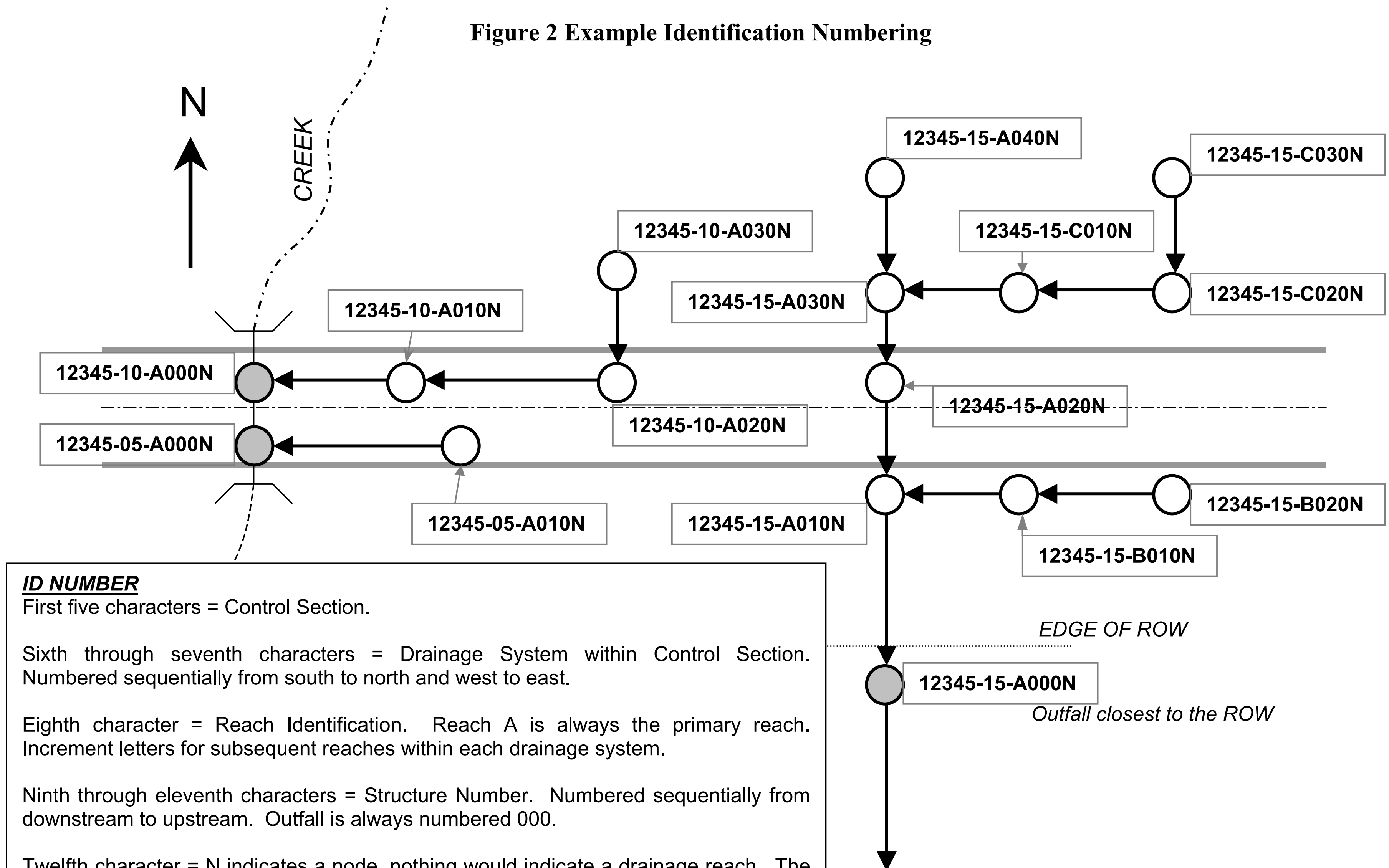
Identification Numbering

Each outfall will have a unique ID number. The purpose of the ID number is for tracking information associated with a given outfall. Each structure will be assigned an ID composed of the Control Section, the drainage system within a control section, a reach within the drainage system and a structure number. The format is described in Figure 2.

Coordinates of Outfall

Outfall horizontal coordinates will be determined within a 10-meter accuracy. This level of accuracy is sufficient for this type of work. A combination of offset distances and a handheld GPS unit with a differential receiver will be used to provide this information.

Figure 2 Example Identification Numbering



ID NUMBER

First five characters = Control Section.

Sixth through seventh characters = Drainage System within Control Section. Numbered sequentially from south to north and west to east.

Eighth character = Reach Identification. Reach A is always the primary reach. Increment letters for subsequent reaches within each drainage system.

Ninth through eleventh characters = Structure Number. Numbered sequentially from downstream to upstream. Outfall is always numbered 000.

Twelfth character = N indicates a node, nothing would indicate a drainage reach. The node on the upstream end of a drainage reach is always the same name as the reach, just with an “N” added. A node can be a manhole or any other point in the system.

Inventory

An inventory sheet will be filled out for each outfall or structure visited. Only one inventory sheet should be filled out per structure. The inventory sheet records the outfall or structure ID, the physical location, and the physical characteristics. Refer to Appendix B for the inventory form.

Screening

A copy of the field screening form is located in Appendix C. Every time an outfall or structure is visited a screening form must be completed. There are several components to conducting a screening at outfalls and structures. These include:

- General information
- Flow measurements
- Observations
- Sample analysis

General Information

The extent of collecting general information is to identify the outfall ID, the date and time of screening, the crew conducting the screening, and the weather conditions at the time of the screening.

Flow Measurements

Dry weather flow rate measurements are intended to provide an estimate of the existing flow rate. Field crews should make an initial assessment regarding the level of effort required to estimate flows. If flow measurements will require more than about 10 to 15 minutes, a description of flow and depth measurement should be provided, or an alternate flow measurement, and/or sampling point should be identified. Flow estimates should not become the primary focus of the dry weather field screening activities. Flow measurements should be performed only after a water quality grab sample is collected to avoid disturbing bottom sediments.

Three methods are outlined for estimating dry weather flow rates at field screening points. These methods include (1) measuring the time it takes to fill a bucket; (2) measuring area and velocity, and calculating flow as the cross-sectional area times the average velocity, and (3) measuring the depth, width, and slope of the channel and calculating the flow based on Manning's equation. The procedures for these methods may be referenced in Appendix D.

Observations

Observation of an outfall or structure condition is a critical component to determining the likelihood of an illicit connection to the upstream drainage system. Below is a list of observations that may suggest the existence of an illicit discharge or connection.

<u>*Floatables*</u>

The occurrence of floatables in the storm sewer system can be one of the most defining pieces of evidence. Floatables can be a variety of things including oil sheens, sewage, and sanitary trash, such as toilet paper. If sewage and/or sanitary trash are observed in the storm sewer system it is an indicator that a sanitary system is connected. Some floatables occur naturally, especially in streams and rivers. Some of these naturally occurring floatables include algae, bryozoans, pollen, and oil like sheens, which may actually be bacteria. For more information about these naturally occurring floatables see the MDEQ documents presented in Appendix E.

If floatables are observed in lakes or streams, attempt to identify a relationship between these materials and any nearby outfalls. If it appears that the floatables are originating from a pipe or outfall, it could be a sign of an illicit discharge.

<u>*Dry Weather Flow*</u>

Dry weather flow can be a valuable observation when identifying systems with potential illicit connections and discharges. Dry weather flow is flow in the storm sewer system even though it has not rained in several days. The presence of flow may suggest that there is an illicit connection or discharge. Dry weather flow may not indicate a problem if the flow is originating from any of the non-storm water discharges listed on page 2. If dry weather flow is observed, other indicators that could provide evidence of illicit connections or discharges should be looked for.

If initial field screening indicates that no flow is present, but suggests an illicit connection may be present, then a check for intermittent dry weather flow should be made. To check for intermittent flows a sandbag should be secured to a rope and lowered into position to avoid confined space entries. Position the sandbag such that it is blocking the lower part of the flow channel of the pipe in question. Secure the top of the rope to a manhole step, or similar item, for easy retrieval. Sandbags should only be left in the manhole for 1 to 2 days and never when the weather forecast is for rain. Re-visit the site within 1 to 2 days looking for signs of intermittent flow and remove the sandbags.

Odor

Strong chemical or sewage odors in a storm sewer may indicate an illicit connection or discharge. If odors are detected, one should look for other indicators including floatables, dry weather flow, watercolor, or stains inside the manhole or pipes.

Foam

The occurrence of accumulations of foam in a storm sewer system may indicate an illicit connection or discharge. Foam can be a natural occurrence in streams and lakes, but if the foam is concentrated around a storm sewer outfall, or appears to be originating from an outfall, it may be an indication of an illicit connection or discharge in that system. For more information on foam see the MDEQ document in Appendix E.

Other Indicators

Other indicators, which may not be significant by themselves, can provide valuable additional evidence to any of the above indicators. These indicators include color, turbidity, the existence of stains or deposits, and the occurrence of excessive vegetation at the discharge point.

Chemical Analysis

When dry weather flow is found, a sample of the flow is to be collected for chemical analysis. The samples are tested, at an analytical lab, for fluoride, ammonia, hardness, total organic carbon, detergents, and *E-Coli*. In the field, temperature and pH are recorded for each sample. All data is then recorded on the screening form.

Sample Collection

If the flow stream has a free fall discharge, the sample bottle may be held beneath the flow stream to fill the bottle. If this is not the case, then a disposable syringe with a pull string may be mounted on a grade rod to collect the sample. A new sterile syringe is used for each new site.

In the case where a syringe with a pull string is necessary to take a sample, the following steps should be used to ensure proper sampling. A syringe should be opened and duct taped to the end of a grade rod. The tip of the syringe must extend below the end of the rod. In order to operate the syringe, string must be tied to the pull section of the syringe and the protective cap from the syringe has to be removed. To obtain a sample, insert the grade rod into the manhole without touching any objects on the way down, such as steps, the rim, or walls. Care should be taken in collecting the water sample to not disturb any sediment. Before pulling the string to fill the syringe, make sure the string is not twisted around the rod, or the string will break. It may take several attempts to fill the bottles full; therefore the bottles must be capped after each attempt.

Three different types of sample bottles are to be filled for each outfall location visited if a flow stream exists. The bacteria test sample should be taken first to reduce contamination. The chemical parameter sample bottles should be taken second and the sample for the field-testing should be taken last.

When collecting a sample, MDEQ water analysis sample collection standards must be practiced. Do not open the bottle until ready to collect the sample, touch the inside of cap or bottle, rinse the bottle with the sample, or use an intermediate container. Make sure to fill the bottle to the bottom of the neck. Be sure each container has the correct water analysis request form associated with it and that it is attached to or in the same box as the sample bottle. Refrigerate all samples during storage prior to shipment or delivery to the lab. Complete a chain-of-custody form for all samples.

Field Testing

Temperature and pH of the water are to be measured in the field immediately after collecting a sample. The pH pen used in the field should be calibrated daily. The test pen can be calibrated by measuring a known calibration standard and adjusting the reading to correspond to the value of the known calibration standard. The calibration instructions and procedures for using the pH pen are located in Appendix G. Each time the pen is calibrated it should be recorded in the calibration log. A copy of a calibration log is also provided in Appendix G.

The thermometer used in the field should be verified daily by comparison with an office thermometer. Each time the thermometer is verified it should be recorded in the verification log. A copy of a verification log for the thermometer is also provided in

Laboratory Testing

Sample bottles from the laboratories are to be picked up prior to the screening activities. Water samples will be collected for both the chemical parameter tests and the microbiology tests where possible and sent to the respective laboratories for analysis. Samples should be kept cool until delivered to the lab. Microbiology tests have a hold time of 24 hours between the time the sample is collected and when the sample needs to be at the laboratory; therefore, appropriate planning is needed on when the samples are collected. Table 1 summarizes the chemical parameters being tested and corresponding bottle characteristics. Samples should be delivered daily to the lab and should not be stored overnight or over a weekend if at all possible.

Laboratory addresses, phone numbers and drop off times are located in Appendix H.

Table 1 Sample Parameter Information

Analyze	Test Method	Bottle Type/Size	Preservative	Hold Time
Ammonia	SM 2340C/ EPA 130.2	150 mL plastic	Sulfuric Acid (H_2SO_4)	28 days
E. Coli	EPA 340.2/300	100 mL sterile plastic	Thiosulfate	24 hours
Fluoride	EPA 350.3	150 mL plastic	None	28 days
Hardness	EPA415.1/ EPA 9060	150 mL plastic	Nitric Acid (NHO_3)	6 months
Surfactant (Detergent)	SM 5540C	250 mL plastic	None	2 days
Total Organic Carbon (TOC)	EPA 415.1/ EPA 9060	40 mL clear glass vials (2)	Sulfuric Acid (H_2SO_4)	28 days

Notes: All samples are grab samples
A total of two bottles are to be collected for TOC per site

During field visits all health and safety procedures must be followed, including the use of proper safety equipment. Notifications procedures must also be followed as stated in this document. Refer to the Health and Safety chapter for more details.

RECOGNIZING A PROBLEM

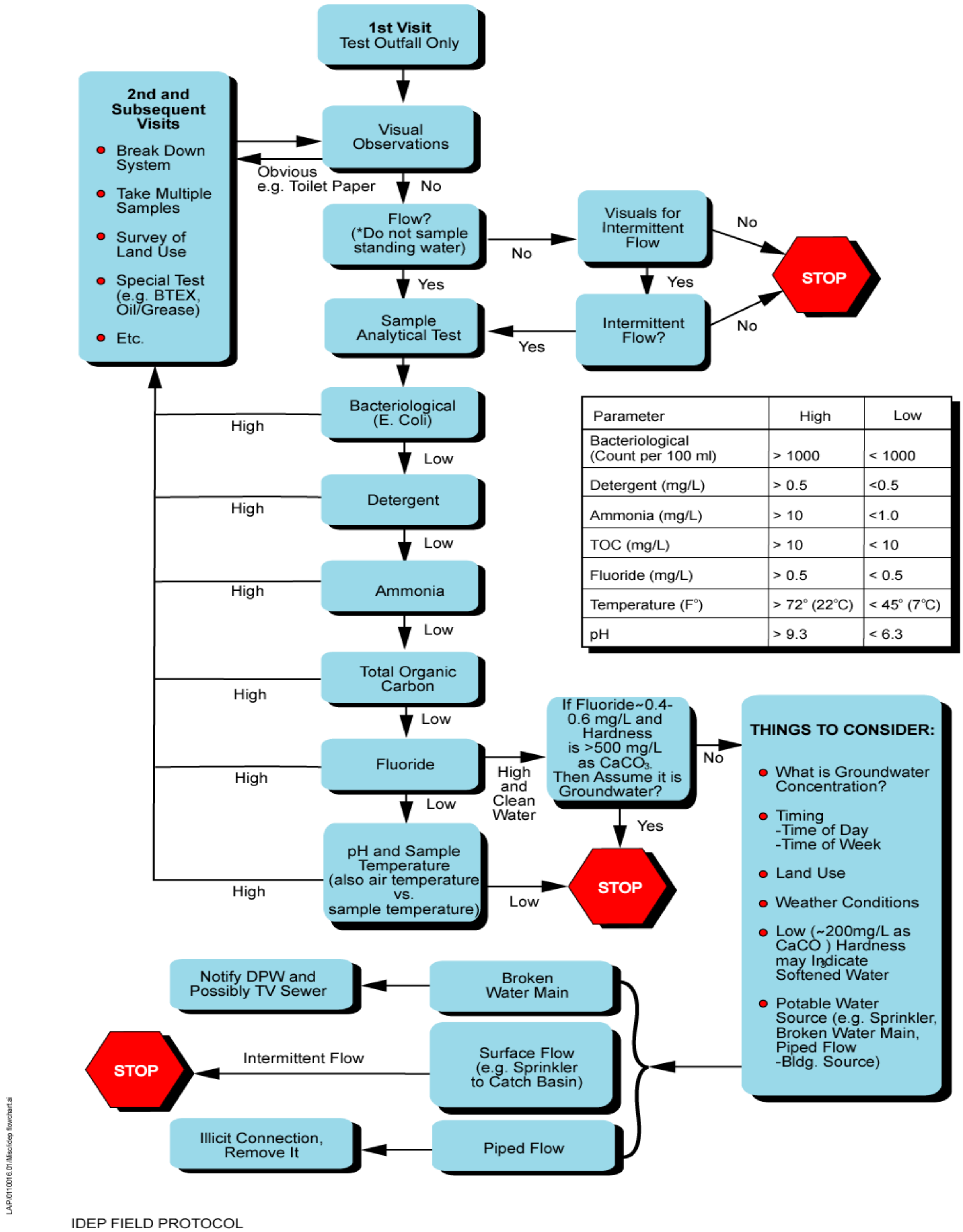
As mentioned before, when dry weather flow is present, a sample of the flow is to be collected for bacteria and chemical analysis. Once laboratory results are available they are entered into the database and a determination is made regarding the likelihood of an illicit connection or discharge. Figure 3 shows the parameter cut off limits for the chemical parameters being tested and indicates whether the sample results are out of the normal range. Figure 3 also shows the decision making process in determining the likelihood of a possible illicit connection for first and subsequent visits.

Tracking Upstream

If an illicit discharge or connection is suspected, additional investigations and tracking will be required at the outfall and within its drainage system. At each subsequent visit the outfall must be sampled. Once the outfall is sampled the dry weather flow should be tracked upstream. Additional sampling within the drainage network should be based on change in the dry weather flow rate, branches within the system, land use, and potential sources. Manhole inventories and screenings must be completed for each manhole visited. This process should be repeated until a potential illicit connection is found.

Contact MDOT immediately with any operation and maintenance issues such as plugged lines. Contact information is located in Appendix H.

Figure 3 IDEP Decision Making Flow Chart



Parameter	High	Low
Bacteriological (Count per 100 ml)	> 1000	< 1000
Detergent (mg/L)	> 0.5	<0.5
Ammonia (mg/L)	> 10	<1.0
TOC (mg/L)	> 10	< 10
Fluoride (mg/L)	> 0.5	< 0.5
Temperature (F°)	> 72° (22°C)	< 45° (7°C)
pH	> 9.3	< 6.3

SOURCE CONFIRMATION

Televising

An illicit connection can be connected directly into the manhole or can be connected into the system between manholes, where visual observations of the illicit connection cannot be made. In these instances televising the storm sewer line may be utilized. If televising is necessary the efforts should be coordinated through MDOT. This method is valuable since access to private property is not available to conduct dye testing.

All illicit connections identified and confirmed should be reported to MDOT and MDEQ immediately.

DATA STORAGE

DATABASE

All of the inventory and screening information is entered or downloaded into a database managed by Tetra Tech MPS. This database will be used to document the progress and results of the program.

TRAFFIC CONTROL

TRAFFIC CONTROL

TTMPS will control traffic control in accordance with the *Michigan Manual for Uniform Traffic Control Devices* by The Michigan State Advisory Committee and MDOT and *Traffic Control Policy and Procedures* by TTMPS.

HEALTH AND SAFTEY

PERSONAL SAFETY EQUIPMENT

Personal safety equipment should include:

- Traffic vest
- Steel toe boots w/metatarsal shield
- Hardhat
- Rubber gloves
- Leather gloves
- Safety glasses

CONFINED SPACE ENTRY

Project personnel will not conduct confined space entry.

MSDS FORMS

MSDS Forms are located in Appendix F.

Appendix A

Field Equipment

Table 2 Field Equipment List

Traffic Safety	❑ Arrow Board
	❑ Traffic Cones
	❑ Safety Vest
	❑ Truck
Inventory	❑ Data forms, clipboard
	❑ Handheld GPS with Differential Receiver
	❑ Manhole hook
	❑ Grade Rod
	❑ Survey Tape
	❑ Folding Ruler
	❑ Sledge hammer
	❑ Survey Wheel
Screening	❑ Stop Watch or a watch with a second hand
	❑ Water Marking Paste
	❑ Grade Rod Fitted for Sample Removal. Disposable syringes mounted to grade rod with pull string and duck tape
	❑ Disposable 60 ml Syringes
	❑ pH Pen
	❑ Thermometer
	❑ Sample bottles laboratory (automated partial chemistry)
	❑ Sample bottles from Health Department (microbiology)
	❑ Instrument Cleaning Supplies
	❑ Cooler
Miscellaneous	❑ Camera, flash, film, 200 ASA color
	❑ Mobile Phone and/or Pager
	❑ Flash Light
	❑ Mirror (for shining into manholes)
	❑ Marking Paint, case
	❑ Storm Drainage Maps
	❑ Phone Numbers (office staff, emergency, MDOT)
	❑ Permit to work in MDOT ROW
	❑ Business Cards and/or Field Badge
	❑ Metal detector
	❑ Spray paint
	❑ Two spades/shovels
	❑ Waders
	❑ Fluorescent dye
	❑ Corks, fish bobbers, etc.
	❑ Pencils, pens, sharpener
	❑ Daily field log to summarize activities
	❑ Truck log
	❑ Accident/ incident report form
	❑ Insurance/registration
	❑ Sunscreen and bug spray
	❑ Antibacterial hand sanitizer (waterless)
	❑ First Aid Kit

Appendix B

Outfall Inventory Field Form

DRAINAGE SYSTEM INVENTORY

GENERAL

Date __________ Time __________ ID ____________________

Crew Initials __________ Chk By: ________ Photographs: Roll #__________ Picture #'s __________

LOCATION (see back side for location sketch)

Community _________________ Control Section ____________________________

Route _________________

Latitude _________________ Determined by ❑ Handheld GPS with Diff Receiver (+/- 10m)

Longitude _________________ ❑ Other (Accuracy __________)

Offset Description: ____

____

____

Receiving Water Body ____

STRUCTURE TYPE

MDOT Outfall ❑ Yes ❑ No ❑ Unknown

❑ Manhole with piped connections

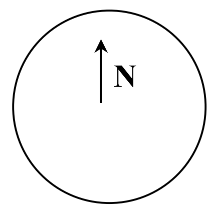
❑ Headwall connecting open channel to pipe

❑ Point within an open channel reach

❑ Pump Station Wet Well

MANHOLE INFORMATION

Direction from MH						
Sewer Size*, (mm)						
Rim Elevation						
Rim to Invert, (m)						
Invert Elevation						
Pipe Material						
Flow Depth, (mm)						



* Include appropriate dimensions and description if not circular

CULVERT INFORMATION

Shape ❑ Round ❑ Rectangular ❑ Other _________ Height (mm)__________ Width (mm)__________

Pipe Material ______________________________ Depth of Solids in Culvert, (mm) ________________

Distance culvert invert ❑above or ❑below ditch bottom, (mm) _____________

Flow Depth in: Culvert*, (mm) ________________ Ditch, (mm)___________

** measure flow depth in culvert to pipe invert, not to top of solids*

NATURAL CHANNEL CROSS-SECTION

Cross-section drawn looking downstream

Channel Material

- ❑ Concrete
- ❑ Brick or tile
- ❑ Asphalt
- ❑ Gravel
- ❑ Earth
- ❑ Rip Rap
- ❑ Vegetative –mowed grass
- ❑ Vegetative – long grass
- ❑ Other – describe

Comments____

LOCATION SKETCH

LOCATION SKETCH CHECK LIST

- ❑ Label Street Names
- ❑ Indicate North
- ❑ Locate manholes by dimensions from property lines, back of curb, edge of pavement, or centerline of road.
- ❑ Sketch catch basins and connections (no measurements necessary).
- ❑ Indicate (if possible) distance to upstream and downstream manholes
- ❑ Landmarks/nearest address, if any
- ❑ Flow direction
- ❑ Sample point
- ❑ Special access/traffic control notes
- ❑ Between mile markers _____ & _____ or _____ tenths past mile marker _____
- ❑ Velocity/depth measure location

Appendix C

Outfall Screening Field Form

DRAINAGE SYSTEM SCREENING

GENERAL ID ______________

Date __________ Time __________ Air Temp __________ ❑Clear/Sunny

Crew Initials __________ Chk By: ___________ Rain ❑Yes ❑No ❑Partly Cloudy

Photographs: Roll #__________ Picture # __________ ❑Overcast

FLOW MEASUREMENTS

Pipe Sampled: Size (mm) ___________ Direction ___________

		General Data		Travel Time Trials	
Depth:	❑ Dry, No Water Present				
	❑ Trace, insufficient to quantify	Depth, (mm)	____________		
Velocity:	❑ Insufficient to quantify	Dist Traveled, (m)	____________	#1 (sec)	____________
Method:	❑ Area * Velocity	Bucket Vol, (l)	____________	#2 (sec)	____________
	❑ Bucket	Channel Slope (%)	____________	#3 (sec)	____________
	❑ Manning's	Channel Material	____________	Avg (sec)	____________
Flow:	______________________	Channel, n	____________	Vel (mps)	____________

Intermittent Flow Check
❑ Not Checked
❑ Left Sand Bag in Channel
❑ Removed Sand Bag, intermittent DWF present ❑ Yes ❑ No
if possible describe frequency, duration, time of day of flow slugs – put in comments section

OBSERVATIONS *(if "other" checked fill in description at bottom of page)*

Odor	❑None	❑Musty	❑Sewage	❑Rotten Egg	❑Gas	❑Oil	❑Other
Color	❑Clear	❑Light Brown	❑Dark Brown	❑Green	❑Grey	❑Black	❑Other
Turbidity	❑Clear	❑Slightly Turbid	❑Moderate Turbid	❑Highly Turbid	❑Opaque		❑Other
Floatables	❑None	❑Trash	❑Sewage	❑Green Scum	❑Oil Sheen		❑Other
Deposits/ Stains	❑None	❑Mineral	❑Sediment	❑Oily	❑Grease		❑Other
Vegetation	❑None	❑Normal	❑Excessive	❑Algae			❑Other
Structural	❑Normal	❑Cracking	❑Spalling	❑Corrosion	❑Settlement		❑Other

CHEMICAL ANALYSIS

FIELD ANALYSIS LAB SAMPLE COLLECTED Chem. Sample ID ______________

Bact. Sample ID______________

	Trial 1	Trial 2	
Temperature	_______	________	°C
pH	_______	________	

Chemistry

Fluoride	______________	mg/L
Ammonia (as N)	______________	mg/L
Hardness (as $CaCO_3$)	______________	mg/L
Total Organic Carbon	______________	mg/L
Detergent	______________	mg/L
❑ E. Coli	______________	per 100ml
❑ Fecal Coliform	______________	per 100ml

Comments____

____

____

Appendix D

Flow Measurement Methods

Bucket Method

This method is typically limited to locations where there is free fall of water at the discharge point. The free fall must be high enough and concentrated along a narrow area so that a calibrated container can be positioned to collect all of the flow.

Equipment Needed:

1. Wide mouthed container(s) (bucket) graduated in known volume increments.
2. Stopwatch.

Procedure:

1. Place container under flow discharge point so that entire flow is collected.
2. Measure the time it takes to fill the bucket to a known volume.
3. Record the time duration and the volume.
4. Repeat Steps 1 through 3 at least once. Repeat steps at least twice, if the results vary by more than 20 percent.
5. Calculate the average time.
6. Compute the flow rate as follows: (Calculations to be done in the office).

   $Q = V/t$

   where:

   Q = flow rate

   V = volume

   t = time required
7. Convert the calculated flow rate to liters per second.

Channel/Pipe Measurements

The second method for estimating flow requires channel measurements. The cross-sectional area of the flowing water and velocity must be estimated. This method should be used to estimate flow rates in pipes or channels where a significant, measurable, or steady velocity is observed and cross-sectional measurements can be readily obtained. The channel measurements can be fairly accurately measured for pipes of a known diameter. However, open channel measurements will generally rely on estimates of a top and bottom width. Velocity measurements will be performed using floats and a stopwatch. Channel pipe flow calculations will be performed in the office.

Equipment Needed:

1. Depth Measurement Rod.
2. Tape Measure.
3. Float(s). These might include corks, fishing bobbers, wooden sticks, sticks and leaves, Cheerios, orange peel, or popcorn. If the float is not recoverable, then only objects that are non-objectionable in streams should be used.
4. Stopwatch.

Procedure:

1. Locate a relatively uniform section of the channel/pipe between 3 to 10 feet long.
2. Mark off a known length of the channel/pipe using available objects, such as rocks or sticks. If the site is at a manhole the diameter (typically 4 feet) of the manhole can be used as the travel length. If the outfall location is at the end of a pipe and the outfall is accessible, a yardstick can be placed into the pipe or measure the length of a pipe section with a tape measure or folding ruler.
3. Use the stopwatch to measure the time required in seconds for a float to travel the marked off distance. If conditions are windy, it is desirable to have a float that is partially submerged. The float can be inserted upstream and timed as it passes the starting point. If swirls or eddies are observed, or if the flow depth is not very deep, this technique may not be applicable.
4. Step No. 3 should be repeated at least twice. If the velocity measurements vary by more than 20 percent a fourth measurement should be performed. The measurements should be averaged after dropping any outliers.
5. Measurements to calculate the cross-sectional area of the discharge should be obtained. For flow in a pipe, measure the depth of flow and the size of the pipe (if the pipe is other than round, sufficient measurements are needed to fully describe the shape of the pipe). For flow in a natural channel, measure the depth of flow, the bottom width of the channel, and the width of the channel at the flow surface.

6. Calculate the cross-sectional area of the flow. Calculations are to be done in the office. The following equations or Table 3 (for partially filled circular pipes) may be used.

   Rectangular Pipes: area = width * depth

   Trapezoidal Channels: area = (top width + bottom width)/2 * depth

   Circular Pipes:

   $$A = \frac{d^2}{4}\left(\Theta - \sin(\Theta)\cos(\Theta)\right)$$

   $$\Theta = \cos^{-1}\left(1 - \frac{2y}{d}\right)$$

   where:

   A = Area

   d = diameter of pipe

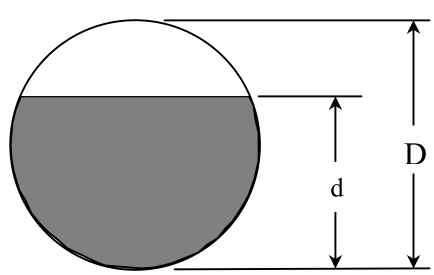
   y = depth of flow

7. Calculate the flow rate and express the result in units of liters per second. Calculations are to be done in the office.

   Flow = Area * Velocity

Table 3 Area and Hydraulic Radius for Various Flow Depths

d/D	A/D^2	R/D	d/D	A/D^2	R/D	d/D	A/D^2	R/D
0.01	0.0013	0.0066	0.36	0.2546	0.1978	0.71	0.5964	0.2975
0.02	0.0037	0.0132	0.37	0.2642	0.2020	0.72	0.6054	0.2987
0.03	0.0069	0.0197	0.38	0.2739	0.2062	0.73	0.6143	0.2998
0.04	0.0105	0.0262	0.39	0.2836	0.2102	0.74	0.6231	0.3008
0.05	0.0147	0.0326	0.40	0.2934	0.2142	0.75	0.6319	0.3017
0.06	0.0192	0.0389	0.41	0.3032	0.2182	0.76	0.6405	0.3024
0.07	0.0242	0.0451	0.42	0.3130	0.2220	0.77	0.6489	0.3031
0.08	0.0294	0.0513	0.43	0.3229	0.2258	0.78	0.6573	0.3036
0.09	0.0350	0.0575	0.44	0.3328	0.2295	0.79	0.6655	0.3039
0.10	0.0409	0.0635	0.45	0.3428	0.2331	0.80	0.6736	0.3042
0.11	0.0470	0.0695	0.46	0.3527	0.2366	0.81	0.6815	0.3043
0.12	0.0534	0.0755	0.47	0.3627	0.2401	0.82	0.6893	0.3043
0.13	0.0600	0.0813	0.48	0.3727	0.2435	0.83	0.6969	0.3041
0.14	0.0668	0.0871	0.49	0.3827	0.2468	0.84	0.7043	0.3038
0.15	0.0739	0.0929	0.50	0.3927	0.2500	0.85	0.7115	0.3033
0.16	0.0811	0.0986	0.51	0.4027	0.2531	0.86	0.7186	0.3026
0.17	0.0885	0.1042	0.52	0.4127	0.2562	0.87	0.7254	0.3018
0.18	0.0961	0.1097	0.53	0.4227	0.2592	0.88	0.7320	0.3007
0.19	0.1039	0.1152	0.54	0.4327	0.2621	0.89	0.7384	0.2995
0.20	0.1118	0.1206	0.55	0.4426	0.2649	0.90	0.7445	0.2980
0.21	0.1199	0.1259	0.56	0.4526	0.2676	0.91	0.7504	0.2963
0.22	0.1281	0.1312	0.57	0.4625	0.2703	0.92	0.7560	0.2944
0.23	0.1365	0.1364	0.58	0.4724	0.2728	0.93	0.7612	0.2921
0.24	0.1449	0.1416	0.59	0.4822	0.2753	0.94	0.7662	0.2895
0.25	0.1535	0.1466	0.60	0.4920	0.2776	0.95	0.7707	0.2865
0.26	0.1623	0.1516	0.61	0.5018	0.2799	0.96	0.7749	0.2829
0.27	0.1711	0.1566	0.62	0.5115	0.2821	0.97	0.7785	0.2787
0.28	0.1800	0.1614	0.63	0.5212	0.2842	0.98	0.7816	0.2735
0.29	0.1890	0.1662	0.64	0.5308	0.2862	0.99	0.7841	0.2666
0.30	0.1982	0.1709	0.65	0.5404	0.2881	1.00	0.7854	0.2500
0.31	0.2074	0.1756	0.66	0.5499	0.2900			
0.32	0.2167	0.1802	0.67	0.5594	0.2917			
0.33	0.2260	0.1847	0.68	0.5687	0.2933			
0.34	0.2355	0.1891	0.69	0.5780	0.2948			
0.35	0.2450	0.1935	0.70	0.5872	0.2962			



Manning's Equation

Manning's equation can be used under certain circumstances to provide an estimate of the flow rate without velocity measurements. Manning's equation requires measurements of the channel cross-section, depth of flow, and slope of the channel, and a roughness coefficient, n, must be estimated. Manning's equation should only be used where the cross-section of the channel or pipe is uniform, the slope and roughness of the channel can be estimated, where measurements are taken at the upstream end of a uniformly sloping channel and where flow discharges freely with no backwater or impoundment due to a downstream condition. Slope of the channel should either be taken off as-builts or should be surveyed.

Equipment Needed:

1. Tape measure and/or depth measuring rod.

Procedure:

1. Measurements to calculate the cross-sectional area of the discharge should be obtained. For flow in a pipe, measure the depth of flow and the size of the pipe (if the pipe is other than round, sufficient measurements are needed to fully describe the shape of the pipe). For flow in a natural channel, measure the depth of flow, the bottom width of the channel, and the width of the channel at the flow surface.
2. Additional observations should include information to determine Manning's roughness coefficient. If possible, photographs should be taken of channel to help select the Manning roughness coefficients, refer to Table 4.
3. Calculate flows using the Manning equation. All calculations are to be done in the office. The Manning equation is:

$$Q = \frac{c1}{n} A^{(5/3)} P_w^{-(2/3)} \sqrt{S}$$

Rectangular Channels

$A = by$

$P_w = b + 2y$

Trapezoidal Channels

$$A = \frac{y(b+B)}{2}$$

$$P_w = b + 2\sqrt{y^2 + \left(\frac{B-b}{2}\right)^2}$$

Circular Channels

$$A = \frac{d^2}{4}\left(\Theta - \sin(\Theta)\cos(\Theta)\right)$$

$$P_w = \Theta d$$

$$\Theta = \cos^{-1}\left(1 - \frac{2y}{d}\right)$$

where:

Q = flow (cms)

c1 = 1.0 for cmsn = Manning's roughness coefficient

A = Area (square meters)

P_w = Wetted Perimeter (m)

S = Channel Slope (m/m)

y = depth of water (m)

d = diameter (m)

b = bottom width (m)

B = top width (width at water surface) (m)

Table 4 Typical Manning's Roughness Coefficient Values

Description	n
A. Closed Conduits Flowing Partly Full	
Cast Iron	
Coated	0.013
Uncoated	0.014
Corrugated Metal	
Subdrain	0.019
Storm drain	0.024
Concrete	
Culvert	0.013
Sewer	0.014
Clay	
Vitrified sewer	0.013
B. Lined or Built-up Channels	
Concrete	
Trowel Finish	0.013
Float Finish	0.015
Finished, with gravel on bottom	0.017
Unfinished	0.017
Concrete bottom float finished with sides of	
Dressed stone in mortar	0.017
Random stone in mortar	0.020
Cement rubble masonry	0.025
Gravel bottom with sides of	
Formed concrete	0.020
Random stone in mortar	0.023
Dry rubble or rip-rap	0.033
Asphalt	
Smooth	0.013
Rough	0.016
C. Excavated or Dredged	
Earth, straight and uniform	
Clean, recently completed	0.018
Clean, after weathering	0.022
Gravel, uniform section, clean	0.025
With short grass, few weeds	0.027
Earth, winding and sluggish	
No vegetation	0.025
Grass, some weeds	0.030
Dense weeds or aquatic plants in deep channels	0.035
Earth bottom and rubble sides	0.030
Stony bottom and weedy banks	0.035
Cobble bottom and clean sides	0.040
Channels not maintained, weeds and brush uncut	
Dense weeds, high as flow depth	0.080
Clean bottom, brush on sides	0.050

* Source: Open-Channel Hydraulics by Ven Te Chow, Ph.D. 1959

Appendix E

MDEQ Fact Sheets

Appendix F

MSDS

Appendix G

Instructions and Calibration Log

pH

Pocket Pal pH Tester
Range: 0 – 14 pH units

Procedure

1. Turn on unit.
2. Remove protective cap from the bottom
3. Immerse the bottom of the Pocket Pal 1 to 3-1/2 inches into the sample.
4. Using the Pocket Pal, gently stir the sample for several seconds. After stirring and when the digital display stabilizes, read the pH value.
5. Rinse the bottom of the Pocket Pal and replace the protective cap.
6. For faster response and longer tester life, place several drops of DI water in the protective cap to prevent the glass bulb from drying out between uses.

Calibration

1. Prepare a pH 7.00 and a pH 4.00 or 10.00 buffer solution.
2. Measure the pH using the tester.
3. If necessary, adjust the Calibration Trimmer (small screws on back) until the reading corresponds to the pH of the buffer.

Notes

- Soak the electrode tip in tap water for a few minutes each week to condition the electrode.
- If pH readings become erratic, replace the batteries.
- Potassium chloride, used as a reference solution electrolyte, may deposit on the tester as a white precipitate. Although the precipitate is normal and does not affect performance, it may be removed with a damp cloth or tissue.

Table 5 Calibration Log

Date	Person	Certified Thermo-meter Reading	Field Thermo-meter Reading	Thermometer ID/pH Instrument ID	Reference Standard (name and concentration)	Instrument Reading against Reference Standard		Comments
						Before Calibration	After Calibration	

Appendix H

Contacts

Refer to Chapter 11 of the Storm Water Management Plan for contact information